INTERVENTIONAL CARDIOLOGY AND SURGERY

Long term prognostic value of myocardial viability and ischaemia during dobutamine stress echocardiography in patients with ischaemic cardiomyopathy undergoing coronary revascularisation

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Objective: To evaluate the relative merits of viability and ischaemia for prognosis after revascularisation.
Methods: Low–high dose dobutamine stress echocardiography (DSE) was performed before revascularisation in 128 consecutive patients with ischaemic cardiomyopathy (mean (SD) left ventricular ejection fraction (LVEF) 31 (8)%). Viability (defined as contractile reserve (CR)) and ischaemia were assessed during low and high dose dobutamine infusion, respectively. Cardiac death was evaluated during a five year follow up. Clinical, angiographic, and echocardiographic data were analysed to identify predictors of events.
Results: Univariable predictors of cardiac death were the presence of multivessel disease (hazard ratio (HR) 0.21, $p < 0.001$), baseline LVEF (HR 0.90, $p < 0.0001$), wall motion score index (WMSI) at rest (HR 4.02, $p = 0.0006$), low dose DSE (HR 7.01, $p < 0.0001$), peak dose DSE (HR 4.62, $p < 0.0001$), the extent of scar (HR 1.39, $p < 0.0001$), and the presence of CR in $\geq 25\%$ of dysfunctional segments (HR 0.34, $p = 0.02$). The best multivariable model to predict cardiac death included the presence of multivessel disease, WMSI at low dose DSE, and the presence of CR in $\geq 25\%$ of the severely dysfunctional segments (HR 9.62, $p < 0.0001$). Inclusion of ischaemia in the model did not provide additional predictive value.
Conclusion: The findings of the present study illustrate that in patients with ischaemic cardiomyopathy, the extent of viability (CR) is a strong predictor of long term prognosis after revascularisation. Ischaemia did not add significantly in predicting outcome.

Patients with chronic coronary artery disease and left ventricular (LV) dysfunction who undergo revascularisation are a high risk population. The prognosis is strongly related to the severity of LV dysfunction with a higher annual mortality among patients with impaired LV function.[1–3] Conversely, contractile function of dysfunctional but jeopardised (viable or ischaemic) myocardium may improve after revascularisation.[4] Several studies showed that when a substantial amount of viable or ischaemic myocardium is present, patients may benefit from revascularisation, since LV ejection fraction (LVEF) is likely to improve.[5–9] Therefore, assessment of myocardial viability and ischaemia has become important in the decision to revascularise patients with ischaemic cardiomyopathy. Moreover, it has been shown that among patients with viable or ischaemic myocardium, the prognosis for patients undergoing revascularisation is superior to that for patients who are treated medically.[10–15] An important issue that remains to be determined is to what extent viability on the one hand and ischaemia on the other hand determine the prognosis after revascularisation. Recent data suggest that viability may be more important than ischaemia for prognosis after revascularisation.[12–15] Moreover, studies with long term follow up after revascularisation are scarce. Accordingly, we have evaluated the relative merits of viability and ischaemia (assessed by dobutamine stress echocardiography (DSE)) for prediction of long term prognosis after revascularisation over a five year follow up.

METHODS

Patient population

The study population consisted of 128 consecutive patients (105 men, 61 (9) years) with ischaemic cardiomyopathy and heart failure symptoms. Patients were already scheduled for revascularisation according to clinical criteria (symptoms, presence or absence of ischaemia, and angiographic findings). Patients with acute coronary syndromes or decompensated heart failure (defined as the need for intravenous inotropic support to sustain an adequate haemodynamic status) were excluded from the study.

Study protocol

The study was prospectively designed to elucidate the long term prognostic value of viability and ischaemia for patients with ischaemic cardiomyopathy who underwent coronary revascularisation. Before revascularisation (within one month), two dimensional echocardiography at rest was performed to identify baseline regional wall motion abnormalities, followed by low–high dose DSE to assess myocardial viability and ischaemia in dysfunctional regions. Also, LVEF was assessed before revascularisation by radionuclide ventriculography. Data on cardiac events (cardiac death,

Abbreviations: CR, contractile reserve; DSE, dobutamine stress echocardiography; HR, hazard ratio; LV, left ventricular; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; WMSI, wall motion score index

myocardial infarction, and hospitalisation for heart failure) were obtained for up to five years of follow up. The local ethics committee approved the protocol and all patients gave informed consent.

Resting and low high dose DSE

Resting and DSE studies were performed with a Sonos 5500 imaging system (Philips Medical Systems, Eindhoven, the Netherlands) equipped with a 1.8 MHz transducer with second harmonic imaging to optimise endocardial border visualisation. Standard parasternal and apical views of the LV were obtained.[16] LV end diastolic and end systolic volumes were measured from the two and four chamber views by the biplane Simpson's rule.[16] One experienced reader blinded to the patients' data took all measurements off line. Low to high dose DSE (up to 40 μg/kg/min plus 2 mg atropine, if necessary) was performed as described previously.[17] Medications, in particular β blockers, were not stopped before DSE. Two experienced observers blinded to the clinical data interpreted DSE studies off line from cineloops. Interobserver and intraobserver agreement for analysis of DSE studies were reported previously (92% and 94%, respectively).[18] Regional function was scored according to a 16 segment, five point scoring model: 1, normal; 2, mildly hypokinetic; 3, severely hypokinetic; 4, akinetic; and 5, dyskinetic.[17] The wall motion score index (WMSI) at rest and with low dose (10 μg/kg/min) and peak dose DSE was calculated by dividing the summed wall motion score at each step by the number of segments.

Assessment of myocardial viability and ischaemia

Myocardial viability was evaluated only for severely dysfunctional segments (score 3 to 5). Segments showing contractile reserve (CR) were considered viable.[5 19] CR was defined as an improvement by at least one point in the wall motion score during DSE, without further worsening.[5 19] Dyskinesia becoming akinesia was not considered to indicate CR.[5 19] WMSI at low dose DSE was considered a measure of CR. The lower the WMSI during low dose DSE, the more extensive the CR. Ischaemia was defined as the presence of a biphasic response (improvement in wall motion at low dose followed by worsening at high dose dobutamine) or a worsening in wall motion at low or high dose dobutamine infusion (with no improvement of contraction at any stage).[5 19] Non-viable myocardium (scar) was defined as severely dysfunctional myocardium without change during DSE; akinetic segments becoming dyskinetic were also considered to be scar tissue.[5 19] Patients with CR in $\geqslant 25\%$ of severely dysfunctional segments were considered to have substantial viability (CR+ patients). Conversely, patients with CR in $< 25\%$ of dysfunctional segments were considered to have minimal or no viability (CR− patients). This cut off value was based on previous work with receiver operating characteristic curve analysis showing that function is likely to recover when four or more segments are viable.[5] Similarly, extensive ischaemia was defined as the presence of four or more ischaemic segments.

Long term follow up

Patients were followed up in the long term by chart review and telephone contact by an independent physician who was blinded to all data. Events were cardiac death, myocardial infarction, and hospitalisation for heart failure. Cardiac death was defined as sudden death or death caused by acute myocardial infarction or heart failure. Myocardial infarction was defined according to classic criteria (symptoms, ECG changes, and increased cardiac enzymes). Hospitalisation for heart failure was defined according to the hospital discharge diagnosis.

Statistical analysis

Continuous data were expressed as mean (SD) and compared by the paired/unpaired Student's *t* test as appropriate. Percentages for categorical variables were rounded and compared by the χ^2 test. Repeated measures were compared by analysis of variance. Univariable and multivariable logistic regression analyses were performed to identify preoperative predictors of cardiac death and composite cardiac events (cardiac death, myocardial infarction, and hospitalisation for heart failure). The variables included in the analysis were age, sex, diabetes, hypertension, hypercholesterolaemia, smoking, medications (β blockers, angiotensin converting enzyme, and nitrates), New York Heart Association (NYHA) functional class, presence of multivessel disease, Q wave myocardial infarction, mode of revascularisation, additional procedures in combination with surgical revascularisation (aneurysmectomy, mitral valve repair), baseline LVEF, resting LV end diastolic and end systolic volumes, and WMSI at rest. In addition, the following continuous variables were included in the analysis: WMSI at low dose and the number of segments with CR (indicating the extent of viable myocardium); WMSI at peak dose DSE, number of segments with a biphasic response or worsening of wall motion, and total number of ischaemic segments (indicating the extent of ischaemic myocardium); and number of scar segments (indicating the extent of scar tissue). Lastly, the presence of CR in $\geqslant 25\%$ of severely dysfunctional segments (as the categorical variable) was also included in the analysis. All variables, independently of the results of the univariable analysis, entered the multivariable stage. Multivariable regression was then performed by a stepwise backward deletion. All variables with $p < 0.25$ remained in the final model. The cardiac event rate during the five year follow up was evaluated by Kaplan-Meier curve analysis. Differences between curves were tested with the log rank χ^2 statistics. For all tests, $p < 0.05$ was considered significant.

RESULTS

Study population

All patients presented with heart failure symptoms and 62% had associated angina pectoris. The mean (SD) NYHA and Canadian Cardiovascular Society classes were 2.6 (1.1) and 2.3 (1.1), respectively. A history of myocardial infarction was present in 118 patients (92%). These patients had had myocardial infarction > 6 months before entering the study.

Table 1 Characteristics of patients with (CR+) and without contractile reserve (CR−)

Characteristic	CR+ (n=64)	CR− (n=64)	p Value
Men	51 (80%)	54 (84%)	NS
Age (years)	62 (9)	62 (10)	NS
CCS class	2.1 (1.1)	2.4 (0.9)	0.03
NYHA class	2.7 (1.0)	3.1 (0.8)	NS
History of MI	57 (89%)	61 (95%)	NS
Diabetes	10 (15%)	5 (8%)	NS
Smoking	32 (50%)	44 (69%)	0.05
Hypertension	39 (61%)	53 (83%)	<0.05
Hypercholesterolaemia	25 (39%)	31 (48%)	<0.001
Number of stenotic vessels	2.5 (0.7)	2.4 (0.7)	NS
Previous CABG	15 (23%)	6 (9%)	NS
LVEF (%)	30 (8)	31 (9)	NS
Aneurysmectomy	5 (8%)	6 (9%)	NS
PTCA	15 (23%)	10 (17%)	NS
On-pump CABG	49 (77%)	54 (83%)	NS
Complete revascularisation	63 (98%)	62 (97%)	NS

Data are mean (SD) or number (%).
CABG, coronary artery bypass graft; CCS, Canadian Cardiovascular Society; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NS, not significant; NYHA, New York Heart Association; PTCA, percutaneous transluminal coronary angioplasty.

Medications were angiotensin converting enzyme inhibitors for 69%, β blockers for 59%, and nitrates for 72% of patients. Coronary revascularisation was performed by percutaneous transluminal coronary angioplasty in 25 patients (19%) and by coronary artery bypass grafting in 103 patients (81%). The left internal mammary artery was used in 98% of the patients. Two patients had mitral valve repair and 11 patients had LV aneurysmectomy (11 patients) in addition to revascularisation.

Myocardial viability and ischaemia

During low–high dose DSE the target heart rate (85% of the age predicted maximum heart rate) was achieved by 113 patients (88%). In particular, 68 of 76 (89%) patients who were taking β blockers and 45 of 52 (86%) patients not taking β blockers achieved the target heart rate.

Analysis of the DSE studies showed that CR was present in 523 (37%) severely dysfunctional segments, whereas in the remaining 874 (63%) segments CR was absent. Similar proportions of the patients with and without β blockers had CR during low dose DSE (34% *v* 31%, respectively, not significant). Ischaemia was present in 257 segments (49%) with CR (biphasic response) and in 58 segments (7%) without CR in which wall motion worsened during high dose dobutamine infusion. Extensive CR (in ⩾ 25% of the dysfunctional segments) was present in 64 patients (CR+ patients), whereas the remaining 64 patients had minimal or no CR (CR− patients). Table 1 summarises the clinical, angiographic, and procedural characteristics of the two groups. In addition, 55 CR+ (86%) and 17 CR− (27%) patients had at least one ischaemic segment during high dose dobutamine infusion. Extensive ischaemia was present in 34 (53%) CR+ and 4 (6%) CR− patients. In CR+ patients, WMSI improved from 3.0 (0.5) to 2.5 (0.6) at low dose and deteriorated to 2.9 (0.6) at high dose DSE ($p < 0.0001$). In CR− patients, WMSI was 2.7 (0.7) at rest, 2.5 (0.7) at low dose DSE, and 2.7 (0.6) at high dose DSE ($p < 0.001$). Table 2 shows the changes in WMSI from low–high dose DSE in the two groups. The changes at low and high dose DSE were significantly higher in CR+ than in CR− patients.

Follow up

During the five year follow up period, 27 patients (21%) patients died of cardiac causes. Nine patients (two CR+ patients (3%) and seven CR− patients (11%), not significant) died of cardiac causes in the early postoperative period (<30 days). In addition, six patients (5%) died of non-cardiac causes. In the survival analysis, these six patients were considered event-free and were censored at their date of death. Three patients (2%) experienced a new acute myocardial infarction and 15 (12%) patients were hospitalised for severe heart failure.

Predictors of cardiac death

Among the clinical variables (table 3) the baseline LVEF (hazard ratio (HR) 0.90, $p < 0.0001$) and the presence of multivessel disease (HR 0.21, $p < 0.001$) were univariable predictors of cardiac death. Also, diabetes mellitus trended to be associated with a higher rate of cardiac death (HR 2.42, $p = 0.07$). Among the echocardiographic variables (table 3), univariable predictors of cardiac death were WMSI at rest (HR 4.02, $p = 0.0006$), low dose DSE (HR 7.01, $p < 0.0001$), and peak dose DSE (HR 4.62, $p < 0.0001$). Also, the extent of scar was predictive of cardiac death (HR 1.39, $p < 0.0001$), whereas the presence of CR in ⩾ 25% of severely dysfunctional segments was associated with a favourable prognosis (HR 0.34, $p = 0.02$) The extent of ischaemia was not predictive of cardiac death (HR 0.60, $p = 0.19$). At multivariable analysis, the presence of multivessel disease (χ^2 12.8, HR 0.20, $p < 0.001$), WMSI at low dose DSE (χ^2 18.2, HR 9.12, $p < 0.0001$) and the presence of CR in ⩾ 25% of severely dysfunctional segments (χ^2 4.6, HR 0.30, $p = 0.03$) were the independent predictors. A lower cardiac death risk was associated with the presence of multivessel disease, a lower WMSI during low dose DSE, and the presence of CR in ⩾ 25% of dysfunctional segments. The best model to predict cardiac death included the presence of multivessel disease, WMSI at low dose DSE, and the presence of extensive CR (χ^2 43.96, HR 9.62, 95% CI 3.99 to 23.14, $p < 0.0001$). Adding the extent of ischaemia to the model did not provide any additional predictive value. Also, the extent of scar tissue did not add significant prognostic information. During the five year follow up, fewer CR+ than CR− patients died of cardiac causes (10% *v* 29%, $p = 0.015$) (fig 1).

Predictors of total cardiac events

Table 4 summarises univariable and multivariable predictors of cardiac events (death, myocardial infarction, and hospitalisation for heart failure). Several univariable predictors were identified: baseline LVEF, multivessel disease, diabetes, surgical revascularisation, WMSI at rest, low dose DSE, and peak dose DSE, number of scar segments, and CR in ⩾ 25% of dysfunctional segments. At multivariable analysis only diabetes, surgical revascularisation, WMSI at low dose DSE, and the presence of extensive CR remained predictive of cardiac events. Ischaemia did not add significantly to the model. During the five year follow up, CR+ patients had fewer cardiac events than did CR− patients (24% *v* 39%, $p = 0.04$).

DISCUSSION

In the present study, we evaluated the long term prognostic value of viability and ischaemia in a large group of patients with ischaemic cardiomyopathy who underwent coronary revascularisation. The presence of a considerable amount of viability (CR) during low dose DSE was a strong predictor of long term prognosis and was associated with a favourable outcome. The extent of ischaemia did not add significantly to the prediction of cardiac events.

Table 2 Echocardiographic characteristics of CR+ and CR− patients

Characteristic	CR+ (n = 64)	CR− (n = 64)	p Value
LV end diastolic volume (ml)	176 (61)	179 (48)	NS
LV end systolic volume (ml)	122 (54)	113 (44)	NS
WMSI at rest	3.0 (0.5)	2.7 (0.7)	<0.001
Number of scar segments	5.4 (2)	7.3 (4)	<0.01
Number of viable segments	7.21 (2)	1.7 (1)	<0.001
Δ low dose WMSI − rest WMSI	−0.56 (0.23)	−0.15 (0.24)	<0.0001
Δ peak dose WMSI − low dose WMSI	0.45 (0.42)	0.14 (0.31)	<0.0001

LV, left ventricular; WMSI, wall motion score index.

Table 3 Predictors of cardiac death

	Univariable analysis			Multivariable analysis		
	HR	95% CI	p Value	HR	95% CI	p Value
Age	1.008	0.97 to 1.05	NS			
Sex	0.56	0.24 to 1.34	NS			
Hypertension	2.79	0.82 to 10.41	NS			
Hypercholesterolaemia	0.92	0.36 to 2.34	NS			
Diabetes	2.42	0.91 to 6.42	0.07			
Smoking	1.21	0.45 to 3.32	NS			
Family history	0.98	0.37 to 2.64	NS			
Previous CABG	0.17	0.10 to 1.27	NS			
ACE inhibitors	1.93	0.73 to 5.11	NS			
β Blockers	0.55	0.26 to 1.17	NS			
Nitrates	1.15	0.40 to 3.37	NS			
NYHA class	1.05	0.41 to 2.67	NS			
Q wave MI	0.54	0.24 to 1.24	NS			
Multivessel disease	0.21	0.09 to 0.49	<0.001	0.20	0.08 to 0.48	<0.001
Mode of revascularisation (CABG)	0.64	0.24 to 1.7	NS			
LVEF	0.90	0.86 to 0.95	<0.0001			
LV end diastolic volume	1.006	0.99 to 1.01	NS			
LV end systolic volume	1.009	1 to 1.02	0.05			
WMSI at rest	4.02	1.82 to 8.91	<0.001			
WMSI at low dose dobutamine	7.01	3.12 to 15.78	<0.0001	9.12	3.80 to 21.92	<0.0001
WMSI at peak dose dobutamine	4.62	2.15 to 9.96	<0.0001			
Scar segments	1.39	1.20 to 1.60	<0.0001			
Segments with biphasic response	0.93	0.76 to 1.13	NS			
Segments with worsening	0.83	0.50 to 1.36	NS			
Total ischaemic segments	0.60	0.28 to 1.30	NS			
Segments with CR	0.88	0.76 to 1.01	0.08			
CR ≥25%	0.34	0.13 to 0.84	0.02	0.30	0.12 to 0.74	<0.03

ACE, angiotensin converting enzyme; CI, confidence interval; HR, hazard ratio.

Prognostic implications of viable myocardium in patients with ischaemic cardiomyopathy

Several studies have shown that patients with ischaemic cardiomyopathy and viable myocardium are at high risk for cardiac events when treated medically.[10–15] Williams *et al*[20] studied 108 patients with ischaemic cardiomyopathy who were treated medically and observed that patients with viable or ischaemic myocardium had more cardiac events than did patients with non-viable myocardium (43% *v* 8%, p = 0.01). The presence of viable or ischaemic myocardium during low–high dose DSE was predictive of cardiac events during the 16 (8) months of follow up.[20] Allman *et al*[15] confirmed these preliminary results in a recent meta-analysis showing that among medically treated patients the cardiac death rate was higher among patients with viable than among patients with non-viable myocardium (16% *v* 6%, p = 0.001). On the other hand, several studies have shown that patients with viable myocardium undergoing coronary revascularisation have a favourable prognosis.[5 12–14 21] Meluzin *et al*[13] showed that patients with > 6 dysfunctional but viable segments had a better event-free survival during 20 (8) months of follow up than did patients with < 6 viable segments. Afridi *et al*[21] showed that the presence of myocardial viability was the only multivariable predictor of a good outcome after revascularisation, after correction for age, severity of coronary disease, and LVEF. Finally, Allman *et al*[15] showed a lower cardiac death rate in patients with viable than in patients with non-viable myocardium undergoing revascularisation (3.2% *v* 7.7%, p < 0.0001). However, in these previous studies, the relative prognostic value of viability and ischaemia was not evaluated. Therefore, it is still unclear whether viability or ischaemia predominantly determines the prognosis of patients with ischaemic cardiomyopathy undergoing revascularisation.

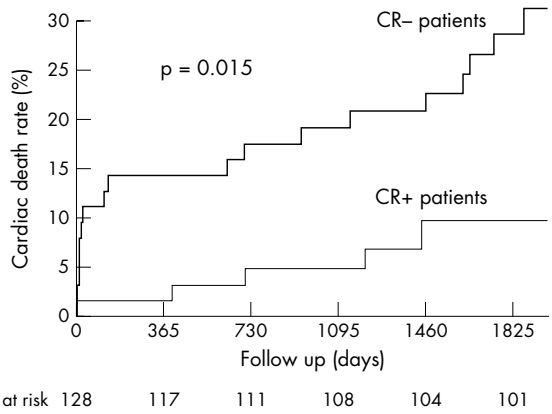

Figure 1 Kaplan-Meier curves showing the cardiac death rate in patients with (CR+) and without contractile reserve (CR−).

Relative prognostic value of viability and ischaemia

Previous studies

Since viability and ischaemia are different aspects of jeopardised myocardium they can be hypothesised to affect prognosis differently. In a previous study by Picano *et al*[22] including 314 patients with acute myocardial infarction who were treated medically, ischaemia at high dose DSE was associated with a higher cardiac death rate during the one year of follow up, whereas viability without ischaemia (sustained CR) had a protective effect on survival. Smart *et al*[23] reported similar findings for patients with chronic LV dysfunction treated medically. Data on the relative prognostic value of viability and ischaemia in patients undergoing revascularisation are scant.[24–27] Pasquet *et al*[24] showed that the presence of viability (indicated by CR during low dose DSE), but not ischaemia, was a strong predictor of good outcome after revascularisation. Similarly, Sicari *et al*[25 26] showed that the greater the extent of viability, the lower the likelihood of cardiac death. However, in these two studies, a low dose dobutamine infusion protocol was applied, limiting a complete estimation of ischaemia. More recently, Sawada *et al*[27] used low high dose DSE allowing for the assessment of viability and ischaemia. They reported that the presence of

Table 4 Predictors of cardiac events

	Univariable analysis			Multivariable analysis		
	HR	95% CI	P value	HR	95% CI	p Value
Age	0.98	0.95 to 1.01	NS			
Sex	0.53	0.57 to 2.90	NS			
Hypertension	2.79	0.82 to 10.41	NS			
Hypercholesterolaemia	0.92	0.36 to 2.34	NS			
Diabetes	2.47	1.14 to 5.39	0.02	2.39	1.01 to 5.69	0.04
Smoking	1.21	0.45 to 3.32	NS			
Family history	0.98	0.37 to 2.64	NS			
Previous CABG	1.21	0.53 to 2.73	NS			
ACE inhibitors	1.93	0.73 to 5.11	NS			
β Blockers	0.65	0.36 to 1.16	NS			
Nitrates	1.15	0.40 to 3.37	NS			
NYHA class	1.53	0.75 to 3.10	NS			
Q wave MI	0.70	0.35 to 1.39	NS			
Multivessel disease	0.38	0.18 to 0.80	<0.05			
Mode of revascularisation (CABG)	0.42	0.21 to 0.84	0.01	0.27	0.13 to 0.55	0.0004
LVEF	0.93	0.89 to 0.96	<0.0001			
LV end diastolic volume	1.005	0.99 to 1.01	NS			
LV end systolic volume	1.006	0.99 to 1.01	0.08			
WMSI at rest	2.34	1.36 to 4.01	0.002			
WMSI at low dose dobutamine	3.41	1.90 to 6.13	<0.0001	6.03	2.97 to 12.22	<0.0001
WMSI at peak dose dobutamine	2.89	1.65 to 5.07	0.0002			
Scar segments	1.24	1.12 to 1.37	<0.0001			
Segments with biphasic response	0.95	0.83 to 1.01	NS			
Segments with worsening	1.10	0.84 to 1.44	NS			
Total ischaemic segments	0.98	0.54 to 1.76	NS			
Segments with CR	0.92	0.83 to 1.02	NS			
CR ⩾25%	0.51	0.27 to 0.97	0.04	0.29	0.14 to 0.62	0.001

ACE, angiotensin converting enzyme.

myocardial viability was associated with a favourable outcome after revascularisation, whereas ischaemia was not predictive of prognosis.[27] In particular, WMSI during low dose dobutamine (a measure of myocardial viability) was predictive of outcome after revascularisation, whereas WMSI during high dose dobutamine (a measure of ischaemia) was not predictive.[27]

Findings of the current study

The findings of the present study are in line with the observations made by Sawada *et al*.[27] The results confirmed that low dose WMSI was a strong predictor of cardiac events, whereas the presence of ischaemia did not add significantly. In addition, the presence of a substantial amount of viability (CR $\geqslant$ 25% of dysfunctional segments) was predictive of outcome. In particular, the cardiac death rate was 10% among patients with CR $\geqslant$ 25% compared with 29% among patients with CR $<$ 25% (fig 1). Also, fewer patients with CR $\geqslant$ 25% reached the composite end point of cardiac death, myocardial infarction, and hospitalisation for heart failure. The predictive value of viability was superior to that provided by clinical characteristics, severity of LV dysfunction, extent of coronary artery disease, and resting echocardiographic variables. Indeed, although smoking, hypertension, and hypercholesterolaemia were more common among CR− patients (table 1), these variables were not predictive for outcome in the regression analyses. Among the clinical characteristics, only diabetes was predictive for the composite end point, but not for cardiac death. At univariable analysis, baseline LVEF was inversely related to cardiac death risk, and WMSI at rest and LV end systolic volume were positively related to cardiac death risk. Also, the extent of scar and WMSI at peak dose DSE were univariable predictors of outcome.

However, these variables were no longer predictive in the multivariable analysis when viability was added. The best multivariable model to predict cardiac death included the presence of multivessel disease, WMSI at low dose DSE, and the presence of CR $\geqslant$ 25% of severely dysfunctional segments (χ^2 43.96, HR 9.62). Addition of ischaemia did not improve the ability of the final model to predict prognosis. These findings, together with the observations of Sawada *et al*,[27] suggest that ischaemia is not the main determinant of the prognosis of patients with ischaemic cardiomyopathy undergoing revascularisation and that viability is a major contributor. In addition, the extent of scar was not predictive in the multivariable analysis, illustrating that the extent of viability is more important than the extent of scar for long term prognosis after revascularisation.

Although data from prospective, randomised trials are still awaited, it appears that in the presence of substantial viability, patients should be considered for revascularisation. For these patients the long term outcome is mainly determined by revascularisation of dysfunctional but viable myocardium, and a large extent of viability is associated with a superior long term outcome.

Study limitations

Follow up coronary angiography was not routinely performed. Therefore, graft occlusion or restenosis could not be excluded. Also, in the design of the study, only patients already scheduled for revascularisation were considered and were followed up prospectively. Since patients who were treated medically were not included, revascularised and non-revascularised patients could not be compared.

Additional end points of coronary revascularisation such as improvement of LVEF or LV volumes were not evaluated in the current study, which is a limitation.

Lastly, we used DSE with second harmonic imaging to assess myocardial viability. Although a very high accuracy in the detection of viable myocardium has been reported with DSE, the subjective and semiquantitative analysis of wall motion by DSE is still a limitation of the study.[18] Tissue Doppler imaging and analysis of strain and strain rate allows quantitative and objective evaluation and quantification of wall motion and may further improve the detection of myocardial viability.[28]

Conclusion

In patients with ischaemic cardiomyopathy, the presence and extent of myocardial viability are strong determinants of long term outcome after revascularisation. The presence of ischaemia did not contribute significantly to the prediction of long term prognosis.

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